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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 17, 1903.

Controlling the Floods of the Mississippi River.

By Prof. Lewis M. Haupt.

Mr. President, Ladies and Gentlemen:

The subject assigned by your committee for this evening is a large one, so that in the time at command it will only be possible to treat of a few generalities. Your attention will therefore be directed chiefly to the humane aspects of the problem, followed by some of the physical conditions which characterize the progress of the improvements, with their results and suggestions as to the remedies which may be applied to still further alleviate the disasters which are all too frequent. Already this season there have been two severe inundations which have risen higher than any previous records, causing great destruction of life and property; but such losses are not unprecedented, for in 1897 the *Public Ledger* said, editorially:

"One of the greatest problems that confronts the Government is the control of the lower Mississippi. Its present condition shows the problem in its fullest force. Levees are broken, towns are inundated, miles of country under water, hundreds of families homeless, many lives lost, and all destructible property over an area of hundreds of miles destroyed. This is a condition likely to occur any year, and it must keep a large section of the most productive land in the United States from being developed, so long as it remains unremedied. Few people will care to settle in a territory where they are liable to be drowned and certain to have their stock and dwellings washed away whenever there is an extraordinary rise in the river. It is a problem not easily solved, for even the expensive operation of building levees affords only temporary relief. This plan, pursued on the Yellow River of China, has had the effect of raising the level of the river above that of the surrounding country, so that when the levees break, as they do every once in a while, a vast tract is inundated and the destruction of life and property is enormous. Can American ingenuity find any better scheme for curbing the Mississippi?"

This prediction was verified a few years after, for, on October 15, 1901, it was officially reported that the floods of the Yangtse Valley had reached their highest stage in fifty years, wiping out villages, destroying crops and drowning thousands of people. Despatches just received from the Kwang-Si district state that 150,000 persons are in danger of starvation, and that women and children are being sold to procure food.

In our own country similar catastrophes have been recorded, beginning with the melting of the snows in the spring, causing the early floods in the Ohio, which have formed numerous crevasses in the levees and a higher stage in the Mississippi River than has ever before been recorded. The stories of suffering, devastation, heroic rescues and deaths have been so constantly presented as to appeal earnestly to the sympathies of the more fortunate sections of the country, and no sooner had the waters subsided than a similar disaster was inflicted upon Topeka, Kansas City, St. Louis and other points from the discharge of the western affluents of the basin. At the same time that these northern sections were suffering from an excess of water, the southern portion of Louisiana was praying for rain to save the rice, cotton and sugar crops from destruction by drought in consequence of the exclusion of the water from the land. What is needed, therefore, is a more equable distribution of water for fertilization and a more uniform stage in the river for navigation. The problem is as old as the world and has been successfully applied in the fertile river bottoms of Mesopotamia and Egypt, which for thousands of years were the principal sources of supply of food to mankind.

In this country, however, the present practice seems to be based not so much on experience in olden times as upon experimentation to meet existing conditions, and in commenting upon the results secured to date, the New York *American* says: "The country is stunned by the appalling horror of the calamity in North Topeka, where fire and flood have combined to slay hundreds. It seems incredible . . . and that such a disaster should have been possible is an arraignment of the engineering skill and foresight of our time.

"The world should by this time have reached a stage where the safety of cities from river floods should be a certainty. . . . Because we have not progressed to this attainable stage, Kansas, Nebraska, Missouri and Iowa are to-day mourning their dead."

In behalf of the engineering profession, it seems necessary to state that the responsibility for these disasters does not rest with it, since Congress has the sole jurisdiction and control of these questions, and its attention has frequently been called by engineers and river men to remedial measures which have not been adopted. The real causes may better be ascribed to politics and local interests, as may be illustrated by the following reported interview with one of the most sagacious railroad magnates of this country, now deceased, who, on being requested to lend his aid to the passage of an Act which would have provided earlier relief to the Mississippi Valley, is said to have replied:

"I have read all of the arguments before Congress. The outlet system is correct and the only way to deepen the Mississippi River. If that were done, what would become of not only my own, but all other railroads coming to New York? They would be ruined, and for that reason he would favor the levee system, for so long as that be kept up, there need be no fears of the Mississippi as a competitor."

A Chicago editor added, whether pertinently or impertinently: "The New Yorkers do not intend to let anything be done that does not pay tribute to New York."

Alas for the rarity of human charity.

It is an unfortunate fact that sectionalism permeates so many of the measures presented to Congress and militates against the general development of the entire country. In this particular instance, however, there is a natural belief that the best means of protecting property from inundation, is to surround it by an earthen dam or dike, so that the earlier settlers in selecting the choice locations for their farms upon lands subject to inundation, were compelled to resort to levees as the simplest and cheapest device for self-preservation. This manifest remedy being innate with all riparian owners, has caused a rapid extension of such protective works as the settlements along the river increased, so that by 1858 it was reported that there was practically a continuous line of levees from Cape Girardeau, Mo., to New Orleans, having an average height of 4 feet. This system, however, proved wholly insufficient for the flood of that year which lasted 199 days, the longest time on record, and covered the whole valley for distances of from 50 to 100 miles to depths averaging 12 feet. In 1823 the levees were only a foot or so high; in 1851 they were raised 5 feet high; in 1859 they were raised 7 feet high, and have been raised and enlarged to meet the requirements of each succeeding high flood which overtopped them until they now average nearly 20 feet.

A Board of U. S. Engineers reported in 1875 that the breaks of the previous year were too numerous to mention. Their total width was 130 miles, and it was added that if the levees do not break the water will run over the tops of them. "The levees are under grade from 6 to 7 feet from

Cairo to New Orleans." This was after 4 feet had been added to the levees of 1858. In 1882 the break at Illaworra, La., in a levee 20 feet high caused damages to the extent of $23,000,000, and it was stated that two or three such breaks will overflow more country than thirty when the levees were from 4 to 6 feet high.*

With a firm faith in the efficacy of an earthen dam to protect and reclaim their farms, and with no knowledge of the various other resources available for the preservation of their lives and property, the riparian dwellers along the lower river are urgent advocates of the continuation of the levee system and instruct their representatives to vote accordingly. Hence, it is that no other systematic effort has been made to modify or improve the conditions inherent to this perennial system of defence—a system which from the very nature of the forces to which it is exposed can never be regarded as complete because of the constantly caving banks which carry with them their superimposed levees.

The efforts to confine the river to a fixed channel by revetting its banks has been discontinued because of the enormous expense and unsatisfactory results, and recourse is had to dredging for relief at low water. But this is not always available, as is instanced by the recent imprisonment of the Monitor Arkansas, near St. Genevieve, Mo., just after the early spring flood had passed out, when it was expected that she might be thrown out of commission for many months or until dredges could be used to open an 11-foot channel to deep water. The Missouri flood, however, released her before the dredges were available.

Physical Elements.—It is a fundamental principle of hydromechanics that *if the capacity for outflow be made greater than that for inflow there can be no overflow*, and yet there are intelligent advocates of levees who seem to be so wedded to the idea that all the water must be confined to the trunk of the river, or be under the control of levees along the banks, that they deny the applicability of the principle to this stream and insist that the more water the more the velocity, and the more the work of scour. But it should be added that if the water is poured in at the upper end faster than it can be voided at the mouth, it must be dammed back and its velocity be retarded by the impounding of the volume, and hence the sediment will be dropped in the stream and the crossing bars be raised because of the higher stages of the flood. This is abundantly proven on a large scale at the South Pass, where the two jetties (levees) retard the flow and have filled up along the entire reach of the river above for 12 miles, so that where at one time the depths were over 70 feet, they are now less than 30, and yet it is asserted that similar congestions in the main trunk do not cause the bed to rise, because careful surveys made at a few years' interval appear to show no such deposits. The question of the rate of sedimentation will be considered later if time permits.

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* See Document No. 123 Senate, Fifty-fifth Congress, First Session, 1897

MAP OF THE MISSISSIPPI DRAINAGE SYSTEM

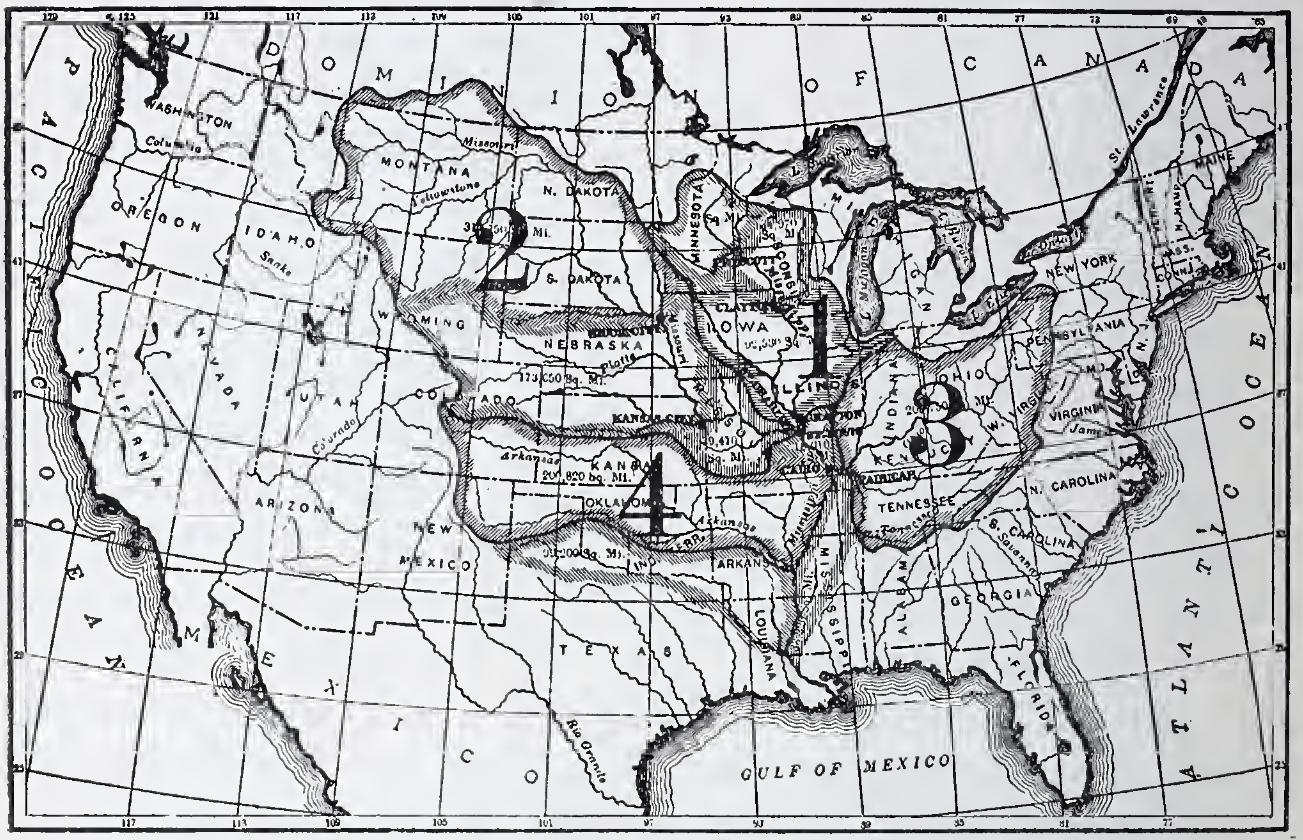

Fig. 1.

Physical.—To understand the problem fully it is important to look briefly at some of the elements which affect the movements in the drainage basin, taken as a whole. These are its form, area, relief, slopes, rainfall, runoff, vegetation, temperatures, etc., most of which may be concisely presented in the form of a tabular statement, as follows:

PHYSICS OF DRAINAGE BASINS OF MISSISSIPPI VALLEY..

Name.	Area.	Annual Rain.	Total c f. of Precipitation.	Run Off, c.f.	Mean Disc.	Ratio.	Elevation at Source.	Length.	Elevation at	
Name	Sq. mls.	in.			per c.f.		feet.	miles	feet	miles
Miss. . .	169,000	35 2	13,800,000,000,000	3,300,000,000,000	105,000	0·24	1,689	1,330	St. Paul, 670	658
souri . .	518,000	20 9	25,200,000,000,000	3,780,000,000,000	120,000	0·15	6,800	2,908	Mouth, 281	—
R. . .	214,000	41·5	20,700,000,000,000	5,000,000,000,000	158,000	0·24	1,649	1,265	Pitts., 699 Mouth, 275	975
ansas . .	189,000	29·3	13,000,000,000,000	2,000,000,000,000	63,000	0·15	10,000	1,514	Mouth, 162	—
. . . . .	97,000	39·0	8,000,000,000,000	1,800,000,000,000	57,000	0·20	2,450	1,210	Mouth, 54	—
oo . . .	13,000	46·3	1,500,000,000,000	1,300,000,000,000	43,000	0·90	210	500	Mouth, 103	—
rancis others	10,500	41.1	1,100,000,000,000	990,000,000,000	31,000	0·90	1,150	380	Mouth, 200	—
ll tributaries	32,400	—	3,600,000,000,000	3,240,000,000,000	—	—	—	—	—	—
er Miss.	—	—	—	—	675,000	0·25	416*	1,286*	Mouth, 0	—
	1,242,900		87,700,000,000,000	21,410,000,000,000						

* High water at mouth of Missouri River.

In connection with this table it is well to give the areas of the natural receiving basins which are subject to inundation by the unrestrained waters overflowing their banks:

AREAS OF NATURAL SEDIMENT BASINS.

	Sq. Miles.
St. Francis, on west bank	6,706
White River " " "	956
Tensas " " "	5,370
Atchafalaya " " "	8,109
Yazoo, on east bank	6 648
Ponchartrain, on east bank	2,001

Total area, 29,790 square miles, which is about 0·024 per cent. of the entire basin. If the entire discharge be confined between levees from Cairo to the mouth of the Red River, where the outlets begin, the area would be reduced to only about 4,500 square miles, or 15 per cent., thus leaving say 85 per cent. from which the river water is intended to be excluded and the natural process of fertilization and sedimentation is cut off. As a large portion of this is swamp land which cannot be drained, because of its level being below that of the river, it would seem to be unwise thus to deflect the only means by which it might have been gradually elevated and made habitable. Moreover, the area included between the existing levees is far from being that ideal trough which should be provided for the maintenance of a uniform flow, so necessary to the creation of a navigable channel, as will presently appear.

From the above table it will be seen that if the floods from all the tributaries were simultaneous the lower river channel between levees would be entirely inadequate and the country would be uninhabitable; but, fortunately, in the Divine economy, the rigid hand of the Ice King seals up the more remote and higher sources of the western floods until those from the Appalachian chain have in large part passed down to the sea.

It is a well-known fact that the slopes of the streams diminish as they approach their mouths and that the sediment which they transport grows smaller in size. It must, therefore, follow that the coarser gravels and shingle deposited in the higher reaches cannot be carried throughout the entire length of the stream and be dumped into the Gulf. It must, consequently, remain in the bed of the river, causing it to rise; and yet it is claimed that such is not the case, for if the bed rises the height of the floods must increase proportionately and the levees also. Upon this denial of bed elevation depends the argument in support of levees, whose advocates maintain that they control the floods and cause compensation for the increased volume by deepening. Careful surveys have been made over long stretches of the trunk of the river, but it is conceded that they prove nothing, while the increasing height of the floods and levees point strongly to a confirmation of the opinion that the bed is silting up. It certainly seems rational that if there is an increasing scour in the higher reaches, that the lesser slopes at the mouth, which are at times negative, would arrest the movement and thus obstruct the discharge and raise the flood-plane. This view is confirmed by the composite cross-sections just issued by the Mississippi River Commission, showing deposit in the low-water areas and caving of banks above that stage.

Rate of Sedimentation.—It has been said by them of old time, that "All the rivers run to the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again." While this is true of the waters of the rivers it is not true of the sediment which they carry. The millions of tons of rain, aided by the frost and winds, denude the mountain fastness, so rich in mineral and fertilizing elements, and feed it to the great hydraulic conveyors which transport it to and deposit it upon these garden spots of the earth, built up of the material supplied by the mountains.

It is stated that since the mouth of the river was at Commerce, just above the Ohio, the deposits have covered some 40,000 square miles, which have been reclaimed from the Gulf and elevated to a height of 285 feet at Cairo, sloping both laterally and longitudinally, so that the river runs on the ridge which it has built up from the bed of the Gulf.

This feature of alluvial rivers is manifest by a glance at the delta, which so clearly exhibits the process of land structure by the long, tapering salients which carry the several arms of the stream far into the Gulf, instead of permitting it to escape down the shortest and steepest slope to the level of the sea. A cross-section of the river also shows the elevation of the banks to be highest along the borders of the stream, and that it falls away in the distance at the average rate of about 3 or 4 feet in each mile, so that the overflow drainage is away from the river and into the bayous and swamps which are its natural sedimentation basins.

It has been estimated that the volume of sediment carried into the Gulf each year varies from 250,000,000 to 278,000,000 cubic yards, but it is also stated that the banks are constantly caving at the rate of about 9 acres per mile of river and that their average height is from 30 to 45 feet, which would contribute about 332,000,000 cubic yards to the bed of the stream, independently of the amount fed by the tributaries, which is no doubt much more, so that the net amount of sediment left in the bed would exceed that deposited in the Gulf, if it be prevented from spreading beyond the bank by levees. Hence it must follow that unless the ejecta are equal to the injecta the excess must contribute to elevation. This may readily be accepted as a fact when it is seen that a single flood may cause deposits on a level amounting to from 6 to 12 inches of mud.

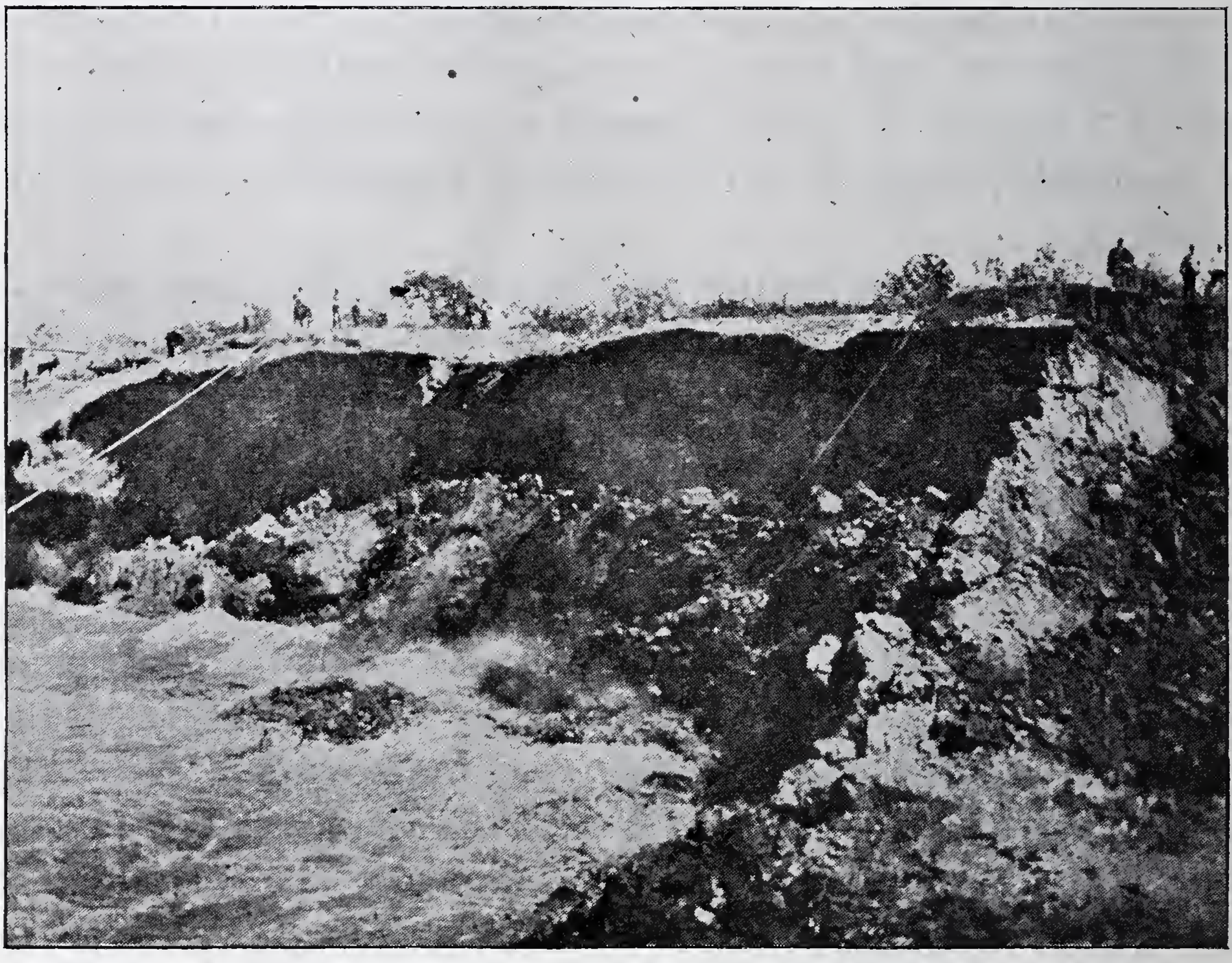

FIG. 2.—Banks in the act of caving.

It is well known that any alternations of velocity will cause corresponding scour or deposit, and that such alternations are caused by variations of cross-section such as are produced by the great fluctuations in the distances between the levees and banks, ranging, as they do, from less than 2 miles to more than 20, so that large areas of deposit are created in the bed of the river, covering in some cases more than 100 square miles.

(See the chart of the Third Engineer District.)

HYDROMECHANICS.—OBSTACLES TO DISCHARGE DURING FLOODS.

Benefit of Outlets.—To dam a river, in whole or in part, restricts its flow and invites deposits. It is immaterial whether the obstruction be composed of stone, wood, earth, silt, water or air; or what its form or position, so long as it encroaches upon the natural waterway.

During the June flood at St. Louis, after the river had begun to fall, the wind veered and raised it over half a foot, causing a breach in the banks and a large additional loss of property.

In 1860 it raised the level of the river near New Orleans 4·6 feet in two hours, inflicting great damage. The level of Lake Borgne was raised 11 feet at the same time. On September 8, 1900, a hurricane swept over the city of Galveston, raising the height of the water 16 feet above the mean Gulf level, and destroyed more than 5,000 lives. Numerous instances might be cited where the winds have operated to impound waters and cause loss of life and property. In a similar manner the waters of a tributary stream in flood have checked those of the main trunk, or the reverse, and caused overflows and consequent loss. Two or more tributaries discharging simultaneously above an engorged reach, must also result in an overflow. These contractions, which are so numerous along the lower Mississippi, operate to retard the flow above them, causing deposits, not scour. It is mainly when the waters of a basin are permitted to discharge freely into a lower level, or under a "head," that scour takes place, hence the use of tidal sluicing basins in many countries to maintain short channels over ocean bars, by flushing at low water. Hence, also, the scouring effects observable in consequence of crevasses in levees, which instead of injuring the lower reaches of the main river are found to improve them.

The Gulf itself is a water dam which, by its inertia, checks the discharge of the river and deposits its silt across the path of the currents, and no amount of jetty extension can change the operation of this law. Moreover, the salt water being heavier than the fresh, buoys the latter up and causes it to float seaward on an ascending gradient so that the limit of the depth of the scour of fresh water is restricted to about 12 feet at a distance of 4 miles from the bank. Temporary modifications may be effected by rapid extensions of the bank, in the form of jetties, but these contractions merely increase the resistance to the discharge, and by raising the flood plane cause new breaches in the low banks above, as at "The Jump and Cubitts Gap." They do not, therefore, relieve the river, but invite further disaster and new outlets.

These commonplace suggestions are prompted by the oft repeated remarks that "the greatest good will be derived from the complete control of the floods between levees," which, it is added, "involves no dangers," and that "it is an error to allow large quantities to escape, hence the outlet propaganda is a 'plague' and is condemned by such high authorities as Generals Humphreys and Abbot."

It may be interesting to state the correct report of these eminent authorities in this connection, as it has been so erroneously quoted and misused to sustain the idea that levees are the sole protection from floods. They say, on page 394, " Physics and Hydraulics of the Mississippi:"

" The facts above cited establish that there is no evidence that any filling up of the river bed ever did occur in consequence of a high-water outlet; and, moreover, that it is impossible that it ever should occur, either from the deposition of sedimentary matter held in suspension or from the accumulation of material drifting along the bottom. The conclusion is then inevitable, that *so far as the river itself is concerned, they *are of great utility.* Few practical problems admit of so positive a solution."

In its application, however, they found some practical difficulties from the fear that Lake Ponchartrain would be filled up in a long period of time. These views as to the utility of outlets are fully sustained by the description of the outlet reach of the river extending from the mouth of the Red River to the Gulf, as reported by a member of the

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* Outlets.

Mississippi River Commission, who says: "In this portion of the river the channel is narrow, averaging about a half mile in width and the depth sometimes exceeds 200 feet. Bank erosion is slight as compared with the fourth reach, sand bars as obstructions to navigation are almost unknown, and neither contraction works nor dredging are required. Here, nature has constructed an ideal channel with sufficient depths at all times for the largest sea-going craft. For nearly the entire length the water is confined to a single channel down to the Head of the Passes, there being but two island, Profit and Bayou Goula, in the entire reach.

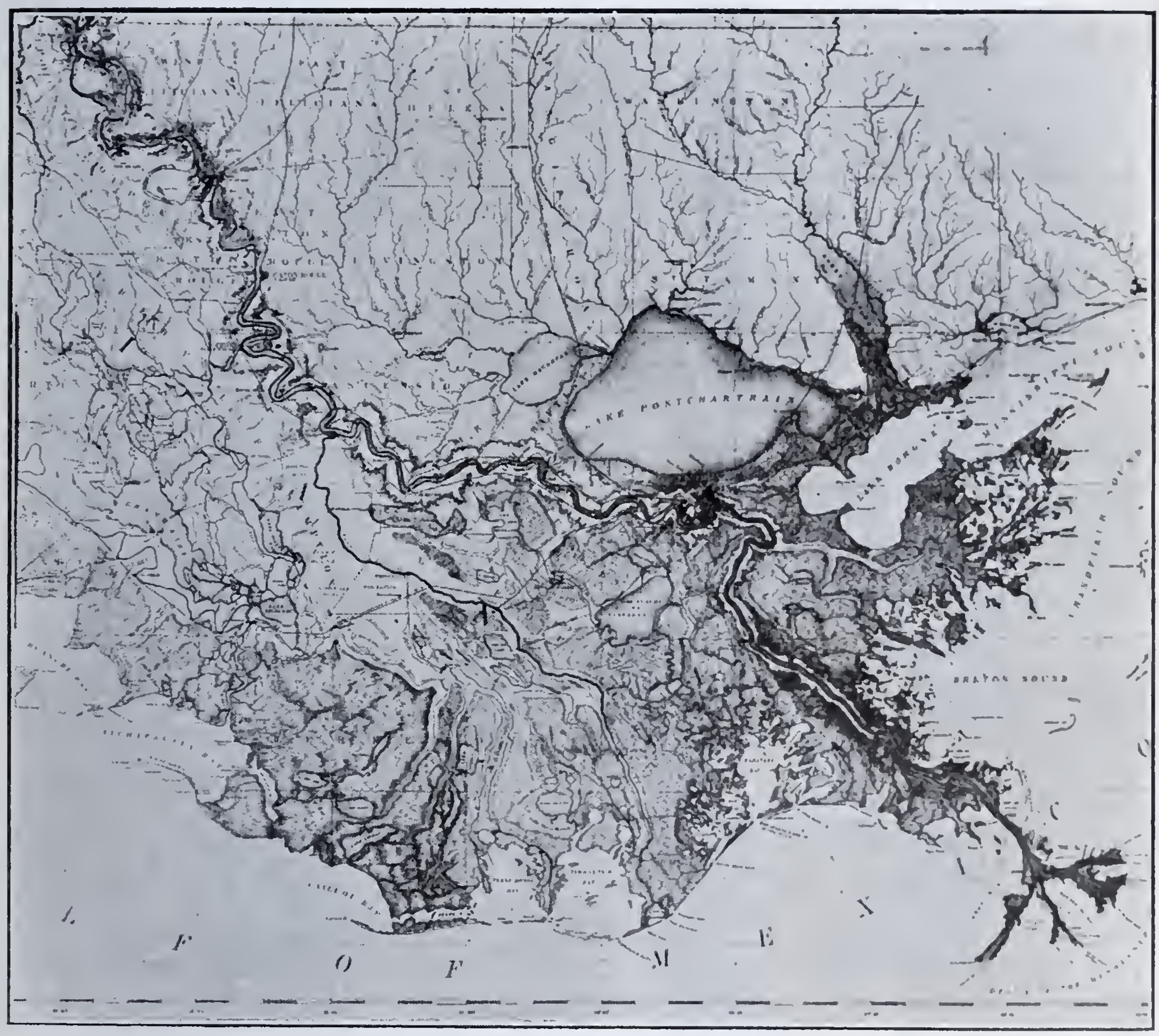
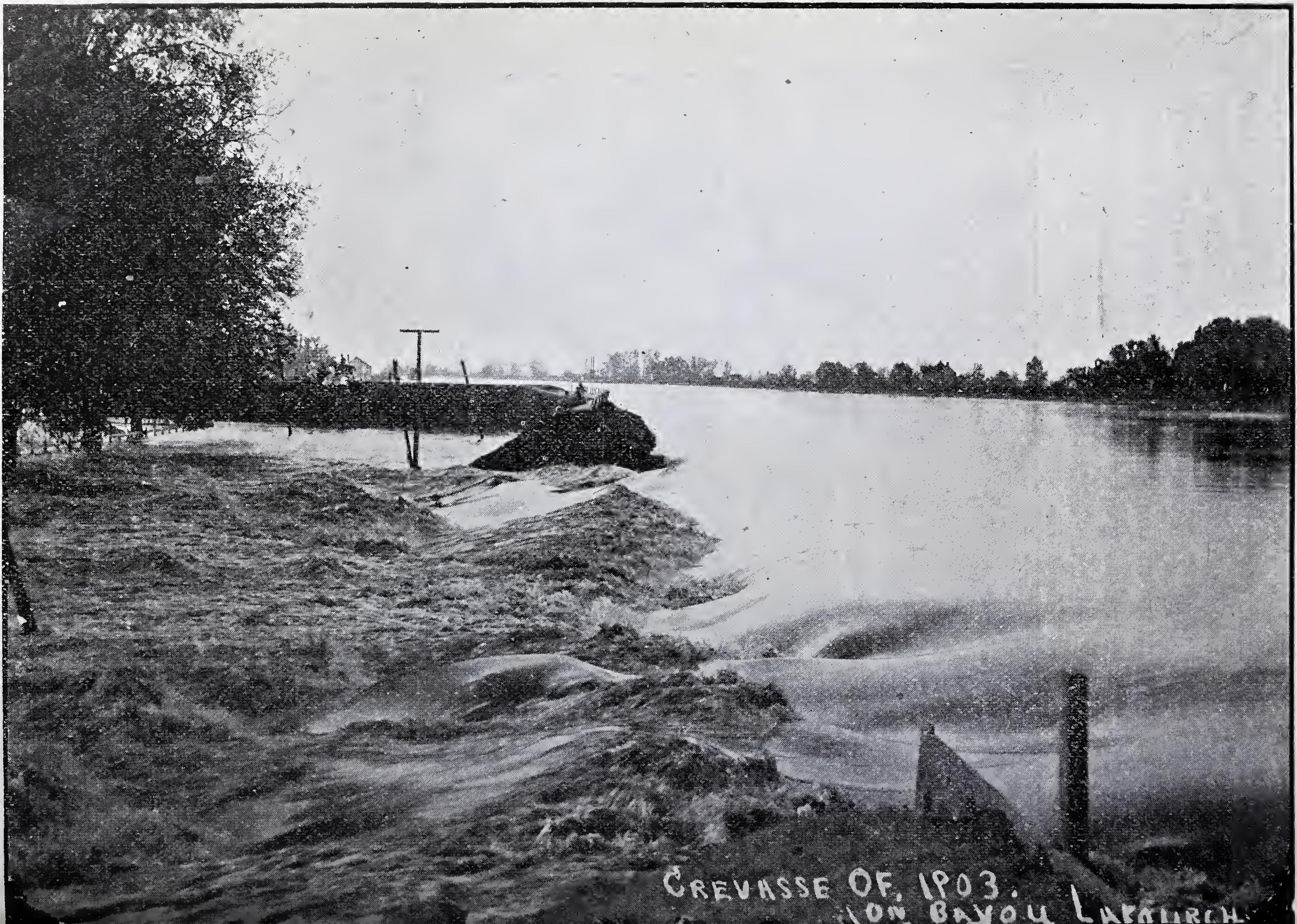


FIG. 3.—The outlet section from Red River to the Gulf, showing parallelism of the levees.

"As the upper limit of the reach at low water is less than 2 feet above mean Gulf level, it often happens that the tidal effect is noticeable throughout its entire length.


CREVASSE OF 1903.
ON BAYOU LAFOURCH

The Red River is the only tributary in the fifth reach which adds to the volume of the main stream.

"There are several outlets through which the waters of the river can flow to the Gulf of Mexico. Some have been closed by levees, as Manchac and Plaquemine Bayous. The Achafalaya, La Fourche, Collet, The Jump and Cubitts are still open, but are gradually filling up with sediments. . . The extreme oscillation in stage recorded up to the present time at New Orleans is 20·7 feet."

Thus nature has demonstrated the great superiority of this stretch of river where the fluctuations are less than one half those of the higher reaches, the channel far more permanent, the banks stable and the protection far superior, because of the safety-valves afforded by the various outlets, which unfortunately are slowly filling as the sediment is left in them from the overflowing waters, thus raising their beds and reducing their capacity. The effect of this congestion was forcibly illustrated by the crevasses which occurred this year on the Bayou La Fourche, in front of Hon. W. E. Howell's plantation, as shown in the accompanying illustration, taken from the *Louisiana Planter* of June 20, 1903. If man does not provide the necessary outlets for the rapid discharge of the floods, nature seeks relief where it is least expected and without warning, carrying ruin in her wake.

The increase in stage due to the extension and elevation of levees by attempting to "control" the entire floods is shown forcibly from the gauge record at Carrolton since 1828, when it registered 14·85 feet; in 1851, it was 15·05; in 1874, 15·35; in 1897, 18·72 and in 1903, 19·05.

Serious Defects of the Levees.—From the very crude manner in which the levees were developed, by localities and individual planters, it was not practicable at first to construct such a system as is desired to train the river in its onward course to the sea. These fragmentary low levees were gradually connected and built up along former lines until there resulted an angular alignment of great variability of cross-section between banks or bluffs causing serious contractions to throttle the floods and impound the high waters in the bed of the stream, thus creating pools and chutes which are so much to be avoided in the maintenance of a navigable channel. For example, the reach extending from the mouth of the Arkansas River to Vicksburg, at the mouth of the Yazoo basin, may be taken as a type. Here it is seen that at the outlet of the Arkansas the distance between banks is about 17 miles, while at Arkansas City it is contracted to less than 2 miles by a salient line of levees which might apparently have been located a few miles farther back, thus saving about 5 miles of levee work and affording a much better discharge. Again, at Greenville a pool exists 8 miles wide by about 12 long at high water, with a similar gorge below it which has caused serious crevasses in this section. So throughout the 213 miles in this district, these features recur at frequent intervals, the worst being at Vicksburg, where the gorge creates the backwater which inundates the lower Yazoo district. It is evident that the relief must come, not by beginning the rectification of the levee alignment at the top, thus pouring more flood water into the lower pools, but by opening the throats of these congested sections from the mouth up and letting the water out more rapidly, thus creating a scour which will deepen the bed and lower the flood, as in numerous foreign rivers. This would reduce the cost of maintaining the levees by diminishing their length and give a better channel with less cost for dredging. The land thus forfeited would be more than gained by the immunity from inundation of the back country and the drainage of other territory.

Discharge Capacity.—To determine the effect of bends upon the discharge of a conduit, some experiments have been made by the writer on tubes of different diameters, two of which represented the low-water channel, one being flexed to conform to its convolutions and the other straight to represent the developed equivalent length, and the time required to pass a given volume of water through them, under a constant head, was noted. From these experiments it was found that the bent tube had a capacity of only 17 per cent. of its equivalent straight tube. Similar tests on the two larger, high-water tubes showed that the one repre-

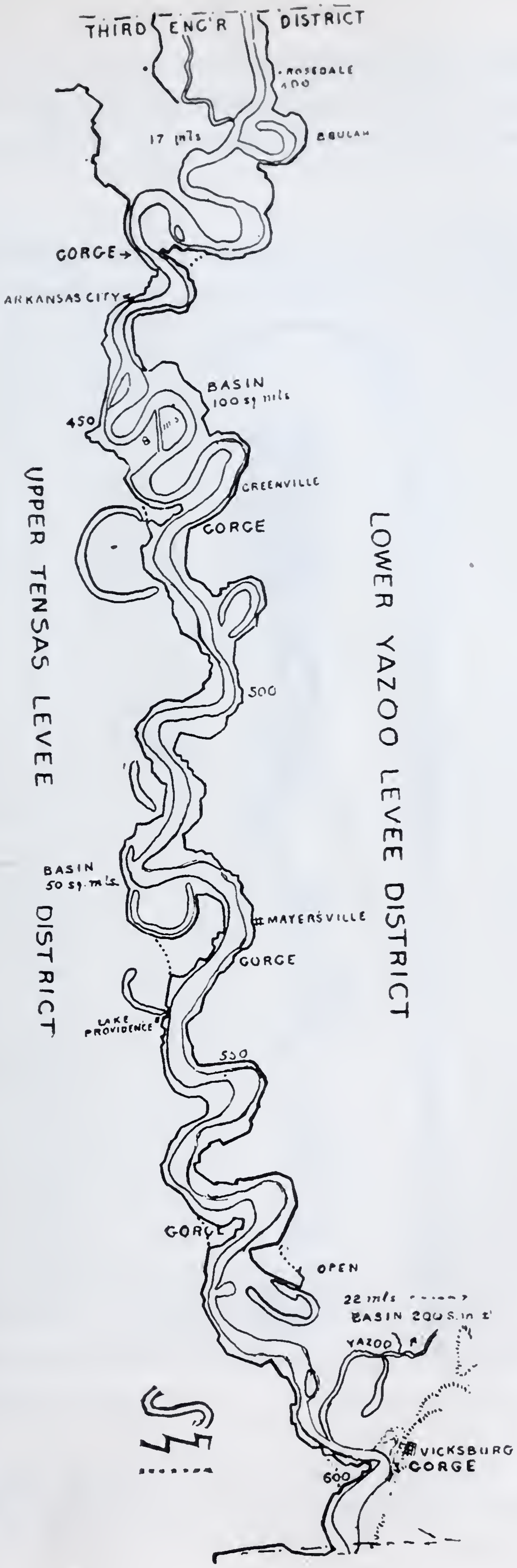
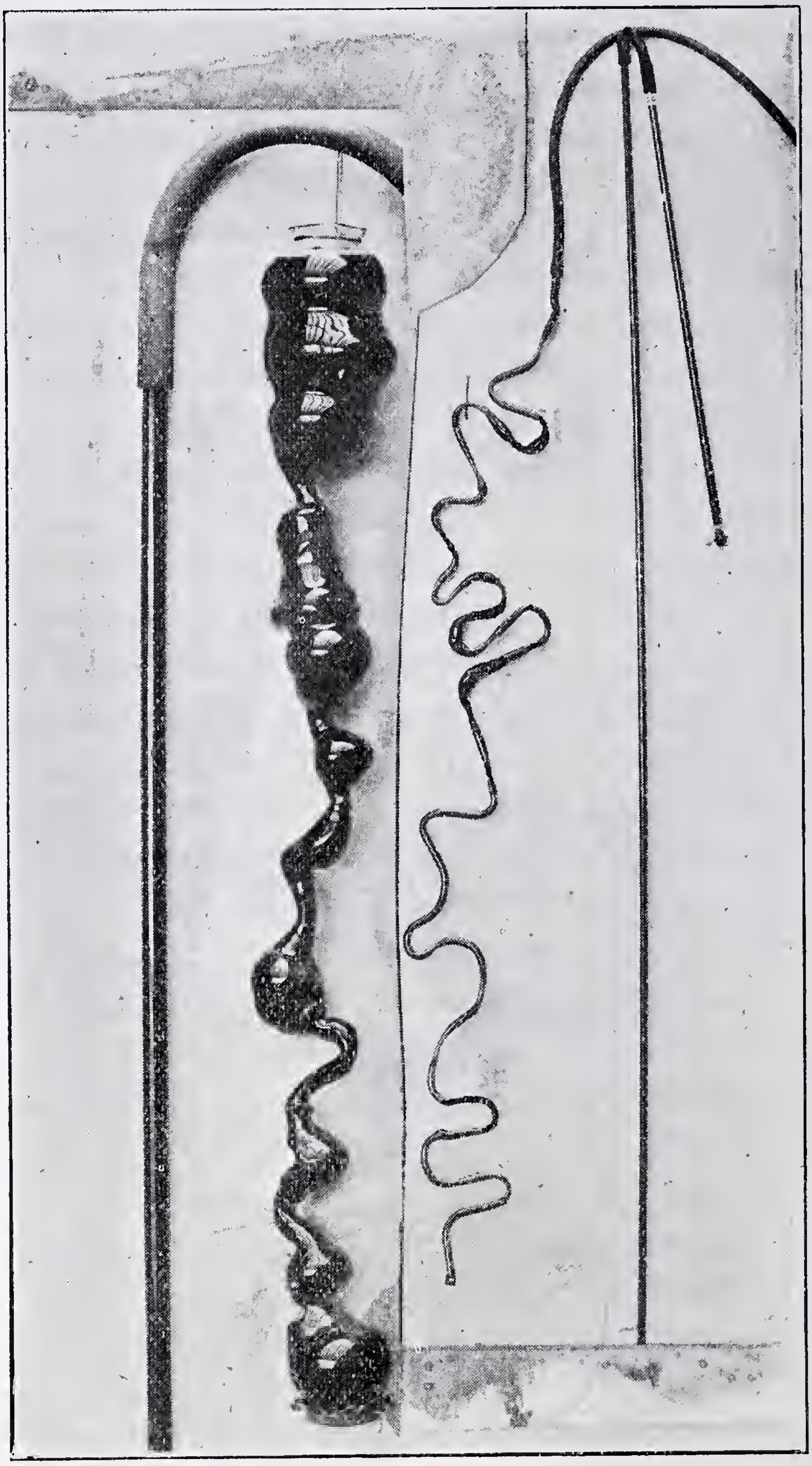

THIRD ENG'R DISTRICT
ROSEDALE
400
17 m'ls
BEULAH
GORGE
ARKANSAS CITY
BASIN
100 sq mils
450
8
m's
GREENVILLE
GORGE
UPPER TENSAS LEVEE DISTRICT
LOWER YAZOO LEVEE DISTRICT
500
BASIN
50 sq. m'ls
MAYERSVILLE
GORGE
LAKE PROVIDENCE
550
GORGE
OPEN
22 m'ls
BASIN 200 S. m 1'
YAZOO R
VICKSBURG
GORGE
600

FIG. 5.

senting the distortions of the levees had a capacity of but 44 per cent. of the corresponding straight tube. In this series of experiments the pools would fill more rapidly than



High-water channels. Low-water channels.

FIG. 6.

the gorges could pass the current, causing overflows, as in a state of nature, and impressing the necessity of a uniformly canalized channel.

Relief Measures.—The resultant of all the experience of the works done on the river shows that there are two distinct problems to be solved. The one relates to the reclamation and protection of the arable lands as a source of revenue and supply, the other to the improvement of the channel of the river as a means of cheap distribution; and the methods now applied to meet these requirements are the attempt to confine the entire flood to the irregular sections between high levees and to improve the low-water stages by the removal of the bars built by the floods, by dredging channels, which are obliterated at the next high water.

Under these circumstances it would seem that the problem is still an open one and that there is room for improvement, and although the engineering profession has no direct control, it may perhaps make suggestions in the interests of humanity and for the betterment of the channel, which, if carried out, may result in less loss and risk to life and property. These remedial measures must evidently be directed towards the prevention of simultaneous floods and accumulation of large volumes of water, which must be carried in a congested conduit for long distances before it can find relief, and therefore no single system will fulfil these requirements but a combination of impounding reservoirs on the tributaries, especially of the western sections, where they may be utilized for irrigation; reforestation of the arid regions; levees with a readjusted alignment and low-weirs at suitable points for spill-ways, to be connected with large subsiding reservoirs in the swampy bayous; and, finally, by the removal of the bars at the delta and opening of all the available and possible outlets to permit of a rapid voiding of the excess of the floods. By such a combination it is believed the navigable channel will be deepened and be made more permanent, the flood plane will be lowered and less arable land be inundated, the height of the levees will not have to be constantly increased, the discharge will be retained for a longer period in the lateral basins, from which it may be fed to the main trunk to sustain a nearly uniform stage and water be stored for irrigation, which is already becoming a necessity in the lower valley because of the exclusion of the flood waters by the levees.

The practicability of the lateral basin system as an auxiliary has been carefully considered and ably presented by James A. Seddon, C. E., for years engaged on the hydraulics of the Missouri and Mississippi rivers. He has shown, by a series of hydrographs, the possibility of so regulating the flow of the river as to reduce the flood heights from its present extreme range of 50 feet to about 25 feet, by the construction of six reservoirs along the back-waters of the St. Francis basin, where the fall is about 120 feet from Cairo to Helena. This work is estimated to cost $32,000,000, including land damages and auxiliary works, and can be built in ten years.

The time is too limited to do this subject justice, but in view of the impending danger from the augmented volume, it is never too late to call attention to the possibilities of relief, which is all that the engineering profession can do until the people of the valley awaken to the necessity of their application and demand a change of plan.